Monitoring activity regimes using pattern recognition of volcanic tremor data. Case studies from Mt. Etna

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The monitoring of the seismic background signal – commonly referred to as volcanic tremor - has become a key tool for volcanic surveillance, particularly when field surveys are unsafe and/or visual observations are hampered by bad weather conditions. It is by now widely accepted that changes in the state of activity of the volcano show up in the volcanic tremor signature, such as amplitude and frequency content. Hence, the analysis of the characteristics of volcanic tremor leads us to pass from a mere monoparametric vision of the data to a multivariate one, which can be tackled with modern concepts of multivariate statistics and pattern recognition. For this purpose we apply a recently developed software package, which combines various concepts of unsupervised classification, in particular cluster analysis and Kohonen maps. Unsupervised classification is based on a suitable definition of similarity between patterns rather than on a-priori knowledge of their class membership. It aims at the identification of heterogeneities within a multivariate data set, thus permitting to focalize critical periods where significant changes in signal characteristics are encountered.

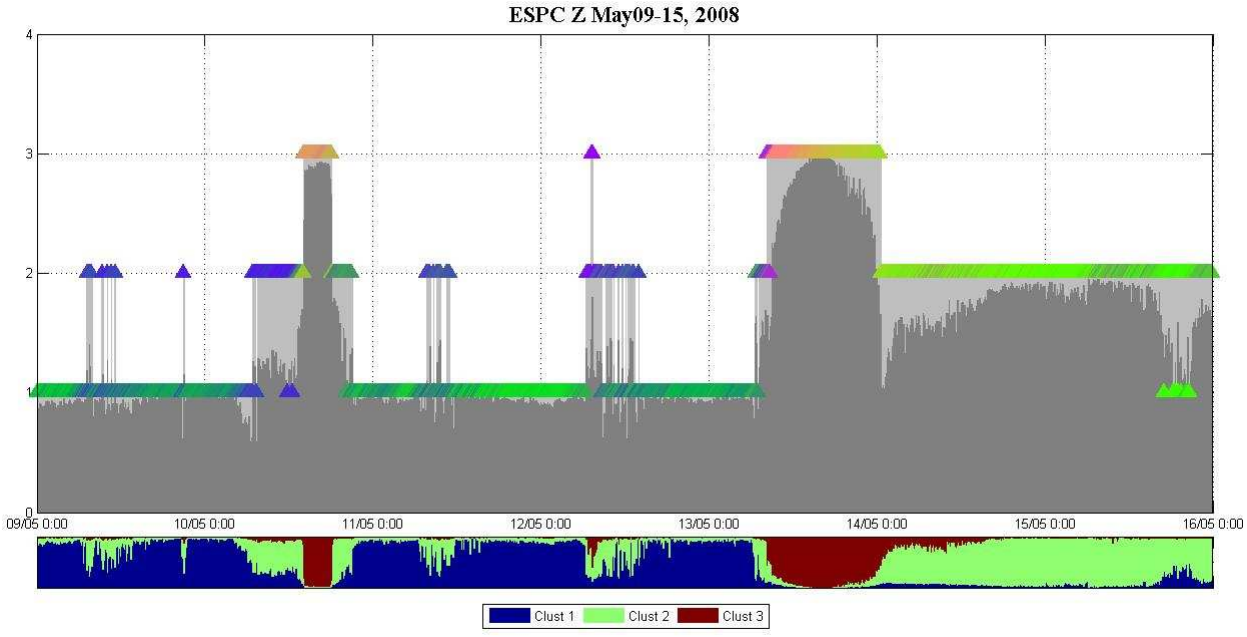

Fig. 1

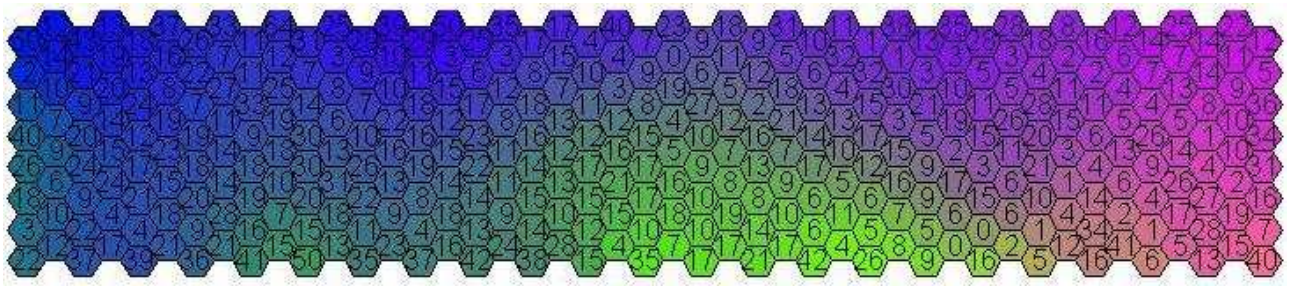

Fig. 2

In particular we exploit the flexibility of the software, as it allows a synoptical representation combining the results obtained with the Kohonen Maps and Cluster Analysis (Figs. 1, 2). For clustering we focus on Fuzzy Cluster Analysis, expressing the class membership of a pattern by a vector rather than a single value or ID. In so doing, we can effectively distinguish between phases in which volcanic tremor characteristics change rapidly and those where changes are smoother. The comparison of the time development of tremor characteristics obtained from other disciplines (such as volcanology, petrology) is intriguing, as it furnishes background information about the physical reasons of changes in tremor features. Particular attention is devoted to transitions from pre-eruptive to eruptive activity, such as the onset of Strombolian activity, often heralding episodes of lava fountaining. We investigate possible differences in the regimes of seismic radiation prior to summit (Strombolian or lava fountaining) and flank activity (opening of fissures, short-lived lava fountaining, lava flow emission) observed in 2007 and 2008, and compare them to changes in the patterns of eruptive activity based on field and other observations available for these years. We also discuss a possible near-real time application of these techniques, which may offer interesting perspectives to monitoring and early warning.